Norton. (S. A.)

CONTAMINATIONS

OF

DRINKING WATER.

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SIDNEY A. NORTON, M. D.,

PROFESSOR OF CHEMISTRY.

OHIO STATE UNIVERSITY, COLUMBUS, OHIO.

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The Ancients reckoned water as one of the four elements. They knew that it played an important part in the tissues of all plants and animals, and believed that it is convertible either into an air or an earth. The first, because it so readily disappeared from their sight on evaporation: the second, because all waters (even the most transparent), when boiled away, left behind a residue, sometimes more—sometimes less, but a something in all cases which was in their phrase, an earth. They held to the doctrine of the "Correlation of the Elements," as we hold to the theory of the "Correlation of the Forces," and imagined that the earthy residue to which they attributed the qualities of "dry and cold" resulted from the action of fire upon water, the "hot" of fire being quenched by the "wet" of water. One hundred years ago (1783), this notion of the elementary nature of water was accepted by all men as true. It agreed with the facts as far as they knew them, and we can now see that they came naturally to this hypothesis by reason of the wonderful property which water has of dissolving nearly all other substances, gases, liquids and solids. Of course, they knew as well as we do, that its solvent powers vary, but they never came to a realizing sense of the fact that solid rock like marble, or granite, would little by little enter it in

state of solution: much less of the conditions which facilitate such solutions or which increase the solvent powers of pure water.

This is so important as to merit more formal statements, viz: (1) Distilled water is capable of dissolving to a greater or less degree almost every known compound. (2) This solvent power is, as a rule, increased largely by heat and by pressure, and (3) also by its first absorbing some substance which in solution will exert a chemical action upon matters afterward exposed to it. Prominent among these "chemical powers" are oxygen, the scavenger of Nature; carbonic anhydride, the Ariel among acids; ammonium carbonate, mildest of alkalies but yet disintegrating the hardest of rocks. Besides, there are other salts, like the chlorides, nitrates and sulphates of the alkalies, and alkaline earths, always open to a partnership, or a trade with any other entity that happens to be thrown in their vicinity. All these, through the agency of water, work out the ceaseless changes which are everywhere manifest in the natural world.

Our knowledge regarding the mutual action and reaction of bodies brought together in aqueous solution is very limited. Sometimes a precipitate is formed, and this fact is easily expressed in the accepted nomenclature of chemistry. But even when this is not the case, we are led to believe that there is nearly always a chemical transfer or transformation of some kind. The strong acid will naturally combine with a strong base, as sulphuric acid with potash, leaving the weaker acid to find a weaker base for its appropriate partner; but this elective affinity is modified and even reversed by a number of conditions. The only one which needs mention at present is the so-called "law of mass" which expresses the unquestioned fact that a very large quantity of a weak solvent may dissolve or decompose substances usually reckoned as insolvent, or prevent their precipitation if dissolved—as for example, barium sulphate is soluble in a large quantity of strong sulphuric acid; or is changed to barium carbonate in presence of a very large quantity of an alkaline carbonate.

Chemical changes, like these indicated, are taking place in enormous quantities wherever water runs or the winds blow. As a final result, the potable water which is offered to our lips is always more or less admixed with various other substances, absorbed or dissolved. If it be bright and sparkling, free from offensive odors, and also free from a marked saline

taste, that is, if it offends none of the senses, it is generally considered acceptable as a drinking water. If water could be obtained chemically pure it would not be palatable. Distilled or even boiled water has notoriously a flat and insipid taste. Some have reckoned such waters as unwholesome. Artesian waters, as is well known, require to be cooled and aerated. In situations where distilled waters are the sole supply, as on board of ships on long voyages, a surrogate of mineral matters is sometimes added to contribute to the taste the expected piquancy. So also, this "taste" frequently becomes a matter of education and, in every town, there are many persons who require considerable additions to the natural waters of the vicinity to gratify their palate. Thus, the average Frenchman takes to *eau sucre*, the young American to carbonated waters—soda water. The mild mineral waters, Seltzer and the like, are in general use in all civilized countries, not so much (as I am led to believe) because of their medicinal effects, real or supposed, as for the added bouquet or·taste. The use of these mineral waters is constantly growing and hardly a drug store on a frequented street is without a throng of clients who obtain nearly all of their drinking water from the natural and artificial Vichy, Congress, Apollinaris and the dozens of other brands which are kept on sale. Some of these waters may act medicinally by reason of the salts they contain, but it must be added that not a few contain so small a quantity of salts that even the attendant deities of the fountain prescribe enormous doses—several quarts per day. Whether for good or for bad, visitors at mineral springs often drink intemperately of the waters; but it can seldom be said that any one has been injured by such over tippling.

These facts are known to every one, they are matters not only of common notoriety, but are thrust upon the public by all sorts of alluring advertisements; and the value attached to these liquids is such, that serious disputes have arisen as to whether a "natural water," which contains 300 grains of sulphate of soda to the gallon, is not a more efficacious therapeutic agent than an "artificial water" which also contains 300 grains of sulphate of soda to the gallon. It has been said that some of these mineral waters really contain enough of salts to enable them to act therapeutically, and very likely this is true. Nevertheless, it is easy to remember that a large quantity of ordinary drinking water acts as a cathartic upon the

average drinker; and if it does not, a pinch of salt, such as the devotee adds to Blue Lick, will accomplish the desired effect. As to the amount of dissolved mineral matters which may habitually be taken in potable water without injury to the health of the drinker—nay even to his apparent benefit, no statement can be made with authority. It has been assumed that 60 grains to the gallon is about the limit, before reaching waters that are to be classed as mineral or medicinal. At the same time, I cannot imagine, either that so large a quantity is necessary to stamp waters as medicinal, or that a tithe of this amount in chlorides, carbonates and sulphates of soda, potash, lime and magnesia, may not be regarded as a useful addition to drinking water. It must, however, be added that some potable waters of the sort have a bad reputation; for example, magnesia waters are thought to be a cause of the goitre; calcareous waters, especially those containing the sulphate, are supposed to induce diarrhea; both are debited with stone and gravel: but these questions cannot be considered as settled.

Of course, it will be understood that there are exceptional mineral waters which contain active poisons, such as copper, lead and arsenic, and that these poisons may be added to the natural water by carelessness or by design. Of such unusual cases, nothing more can be here said. Summing up the facts known in regard to mineral matters dissolved in drinking waters, it is pretty generally agreed that with the exception of copper, zinc, and lead salts accidentally introduced by fault of the plumber, a moderate amount of such mineral matters as salts of the alkalies and of the alkaline earths, must not be regarded as injurious contaminations. It is, however, true that a change of waters from soft to hard has induced diarrhea in susceptible persons. Generally speaking, the effect soon passes off, and habit will, in less time than is usually imagined, change to the opposite idiosyncrasy.

Before leaving this point, it is necessary to note that some mineral matters are present in river waters, not dissolved, but merely held in suspension. These matters are generally fine clay and sand which are neither soluble in water nor in the alimentary canal. If swallowed, they may possibly somewhere collect into a sand-bar or a mud dyke in the canal; but cannot in any way enter into the circulation. Nevertheless, they may also act as mechanical irritants. Such muddy waters are not attractive, and require a long time to settle clear; but, as a rule, they

are quite soft, and, when properly filtered and cooled, are among the most palatable of potable waters.

Hitherto your attention has been directed only to the mineral or inorganic matters present in potable water. Of far greater importance to the consumer is the presence of organic matter, whether vegetable or animal.

ORGANIC MATTER is a large word, and has become a bugbear to the laity if not to the faculty. Here it is of the utmost importance to differentiate. In the first place, "organic matter" includes such bodies as starch, sugar, or the carbohydrates, and such as albumin, casein, fibrin, or the nitrogenous bodies, as well as other groups. It must be granted that almost any one of such organic compounds, as would properly be even mentioned in a report like this, would be classed as an aliment and, as such, be, in appropriate quantities, a desirable addition to our food. Every day we mix in our stomachs, with the water we drink, matters that include starch, sugar, albumin, fibrin, casein, and the rest of the list, and we flatter ourselves that the more extensive the mixture the better shall be the result. At any rate, we do not reckon that flour, sugar, eggs, meat, cheese, peas, etc., are poisons, and are utterly unconscious that these substances are classed among organic matters. For all our short-sightedness or actual ignorance, these are the very substances which furnish the "organic carbon" and the "organic nitrogen" to potable water. Those which contain nitrogen are thought to be especially of an alarming character, as these only can be transformed into ammonia, nitrites and nitrates. But a nitrate is not in itself a terror, a good sized dose of salt-petre is not septic, nor is ammonia. A nitrite, being both an oxidizing and a reducing agent, is to be regarded with more suspicion; but not enough is known of the action of the nitrites to lay any charge against them, with any certainty of proof. It is also to be noted that the amounts of nitrogenous products of decay are in most cases very small and are, chemically speaking, incapable of producing great changes. The products of the decomposition of non-nitrogenous matters have in themselves never been charged with being poisons or the immediate sources of disease. They are principally carbonic anhydride and alcohol—of course extremely dilute and rapidly changing to other products, like acetic acid. Whence then comes the almost universal outcry against organic matters?

Dead organized matters, that is, the whole or parts both of vegetable and animal remains, are found in water in three states: First, As fresh and undecomposed matters suspended in water. These are certainly without harm and are in no way to be regarded as sources of present harm—any more than so much starch or albumin. Second. As matters in a state of active decomposition. This decomposition naturally takes place by means of certain ferments: (*a*) soluble, but not containing living forms; (*b*) insoluble and always accompanied by, if not consisting of, living organisms of a low order. Among the soluble ferments must be reckoned such bodies as diastase, emulsin, ptyalin. Among the organized ferments are such structures as the yeast plant, the various bacteria and other low forms of life—recently brought to our knowledge by the researches of Pasteur and his associates. The latest researches indicate that the conversion of the albuminoids to nitrites and to nitrates is due to organized ferments of similar character, and we all know what Koch would have us believe about the specific germs of disease. Here let it be noted, that it is not necessary that these theories be accepted regarding the office of such ferments. They are always present when nitrogenous matters are in active decomposition and their presence may be taken as a sign that such putrefactive changes are in process, whether they are the active agents in causing them or not. At all events, putrefying organic matters have in all ages been justly regarded as objects of suspicion even when disease has not been directly traced to them. Third, The organic matters may be the final products of such changes—the bacteria and other such bodies will have done their work and have died; the products of decay, carbonic acid, ammonia, or the nitrates, will be dissolved in water, and as already stated can hardly be viewed with alarm.

Nevertheless, the presence of ammonia, of nitrites, or of nitrates, in water is a proof of a previous organic contamination and a suggestion that the contamination has not fully run its course. Hence in analyses of potable waters, the actual per cent. of ammonia found represents the decomposition which has already taken place; the per cent. of the so-called albuminoid ammonia, that is, of ammonia which may be obtained by the action of chemical reagents, like an alkaline solution of a permanganate, represents the uncompleted decay of other nitrogenous matters. In this view of the matter, such products serve

only to call attention to a possible source of danger—because these nitrogenous matters are the necessary nidus of organized ferments and supply the food which is as necessary to their growth and reproduction as water, and starch, and oil and albumin are to the nourishment of human beings. In some cases, they furnish indications whereby a future contamination of the sort may be prevented.

If these points are well taken, fresh organic matters are harmless, when merely suspended in water, but are potential elements of contamination. The final products of fermentation and of decay are also harmless unless present in large quantities. Some of these products, as carbonic anhydride, contribute notably to the pleasant taste of drinking water.

The second stage is, therefore, the only one which need cause alarm; but, if the researches of modern science count for anything, the presence of even a trace of animal matters, say 1 part in 1,000,000 in a state of active decomposition, or of the microscopic living forms which attend putrefactive decomposition, may justly give occasion for suspicion and fear. All filth must be regarded with horror as likely to be a hot-bed of putrefactive ferments which may possibly enter the drinking water of a community as sewage, and cause serious epidemics of diarrhea, of dysentery, of typhus, and of cholera itself. Not a few instances of such epidemics have been traced directly to the water supply. Most to be dreaded of all organic products are those derived from man. All human excrements are in a sanitary sense dangerous, but most especially those derived from persons who are at the time suffering from diseases like those mentioned. There seems to be very little doubt that drinking water is one of the principal agents by which zymotic diseases are propagated. Our National Board of Health last year instituted a special investigation as a contribution towards establishing or refuting this belief.* The facts which have already been gathered both in America and in Europe show a manifest relation of cause and effect as between putrefying and disease freighted dejections and epidemics of cholera, dysentery and typhus. No chemist has yet attained the skill sufficient to detect the ferment of such diseases, and no microscope is piercing enough to exhibit their germs. They lurk unsuspected and become manifest only by their fruits. Our warning signals are

*Their report was not ready in June.

principally those which indicate that a nitrogenous decay has taken place.

I have neither space nor time to enlarge upon these matters, much less to give in their necessary detail the numerous cases which have established the foregoing points. The lesson which sanitary science has prepared for humanity in regard to drinking water is briefly this:

Mineral matters present in water to not too great an excess seldom are to be regarded as a source of disease. Organic matters in decay, filth of all sort, sewers, privies, cess-pools, are always to be viewed as a probable source by which disease may be propagated and especially when they are present in drinking water. The presence of an excess of chlorine may indicate that urine has entered the well or spring.

It is proper to note that organic life, such as growing plants, and even animals may act to purify contaminated waters. These organized bodies are like other plants and animals, and are matters in suspension. The aquaria show how these two classes may balance. It has been a question hotly debated by the Rivers Pollution Commission and the London Supply Board as to whether running waters are self-purifying. The last report of the London Board seems to establish its probability. They hold, and apparently with sufficient reason, that running water, contaminated by vegetable matters or by animal offal, speedily becomes sufficiently pure for drinking, because:

1. Little of sewage is dry matter.
2. Much of the solid portion will speedily settle to the bottom.
3. A notable part, especially of fresh matters, will be consumed by the fish and other inhabitants of the stream.
4. Another part will be burnt up by the large proportion of oxygen present always in running water, and
5. Finally the small proportion left will be so diluted as to be rendered harmless.

Shallow wells have no such safeguards and are often unfit for use. On the other hand, deep wells generally furnish a palatable water quite free from organic impurities, containing less, in fact, than rain water. This is due to the fact that underground waters are also oxidized by underground air, and, under favorable circumstances, completely.

Space and time forbid further consideration of the sources of water, and means of storing and of purifying them, but I have perhaps said enough to enable me to state what constitute impurities of drinking water.

These are an excess of inorganic matters dissolved or suspended—which render the water less pleasant to the eye and agreeable to the palate.

A small amount of organic matter in the state of decomposition is a most serious contamination and dangerous, even though too small to be detected either by the microscope or by chemical reagents. Finally, natural waters, at their sources wholesome and palatable, may be so contaminated before they reach the consumer, as to become suspicious or even dangerous. Too great care is not likely to be given to the collection, stowage in reservoirs and final transmission through pipes, of water intended for household use.

A large amount of absorbed oxygen and carbonic acid is to be reckoned desirable. A small amount of dissolved salts of the alkalies and alkaline earths is not unwholesome.

The best water for drinking is that obtained from perennial springs or deep wells, when not too hard; then that from rains and mountain streams.